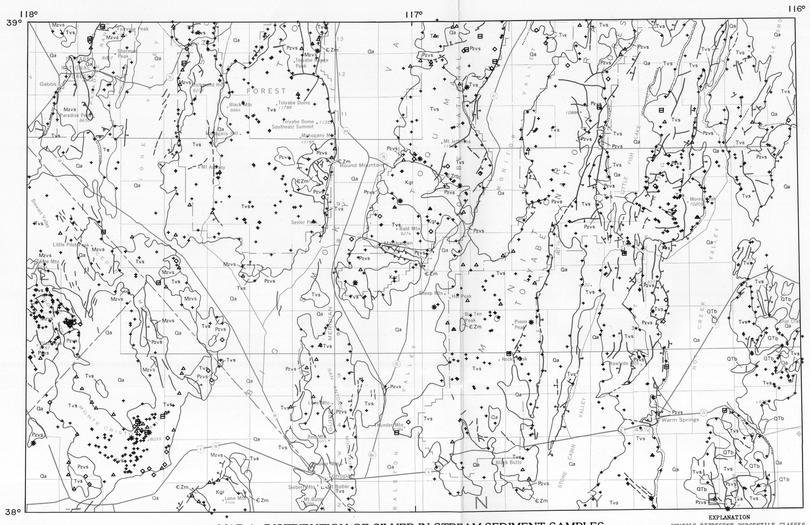
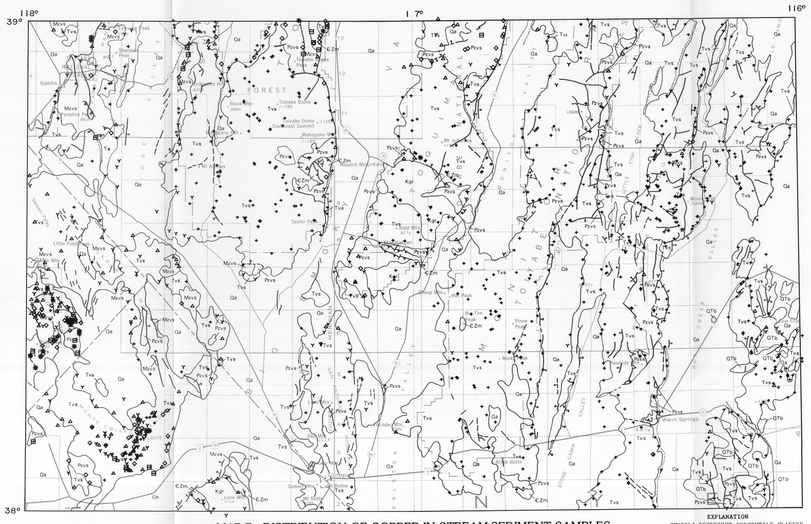


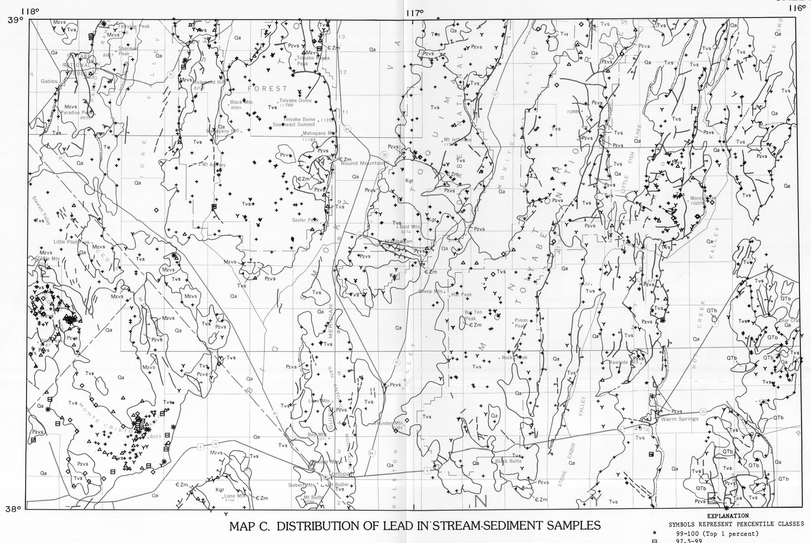
MAP A. DISTRIBUTION OF SILVER IN STREAM-SEDIMENT SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



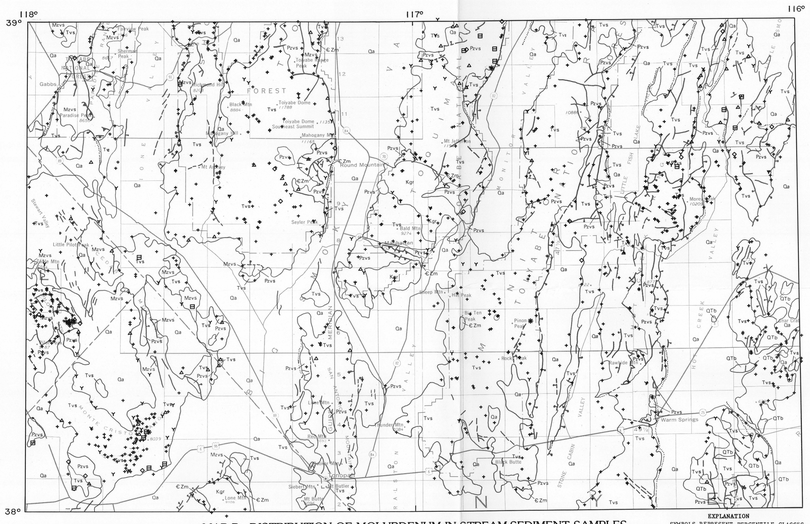
MAP B. DISTRIBUTION OF COPPER IN STREAM-SEDIMENT SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



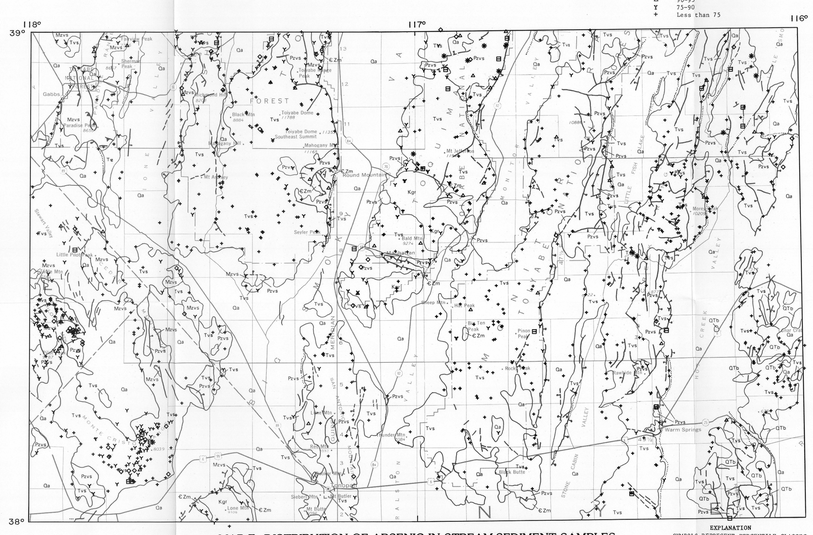
MAP C. DISTRIBUTION OF LEAD IN STREAM-SEDIMENT SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



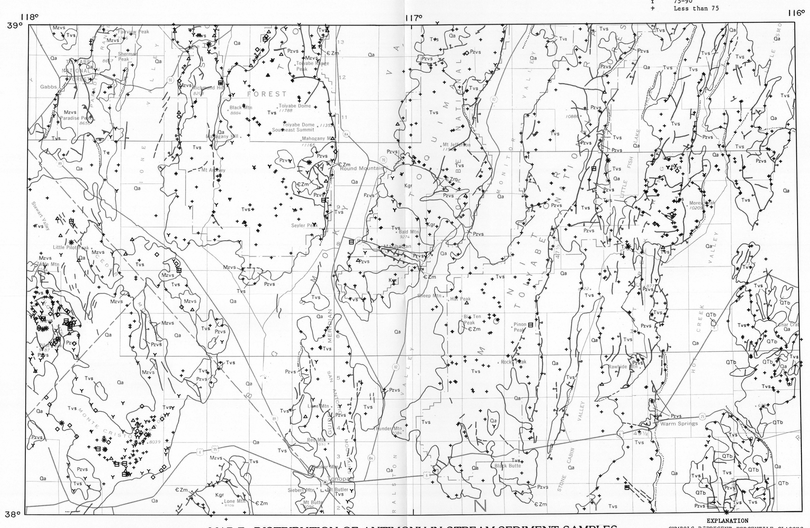
MAP D. DISTRIBUTION OF MOLYBDENUM IN STREAM-SEDIMENT SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



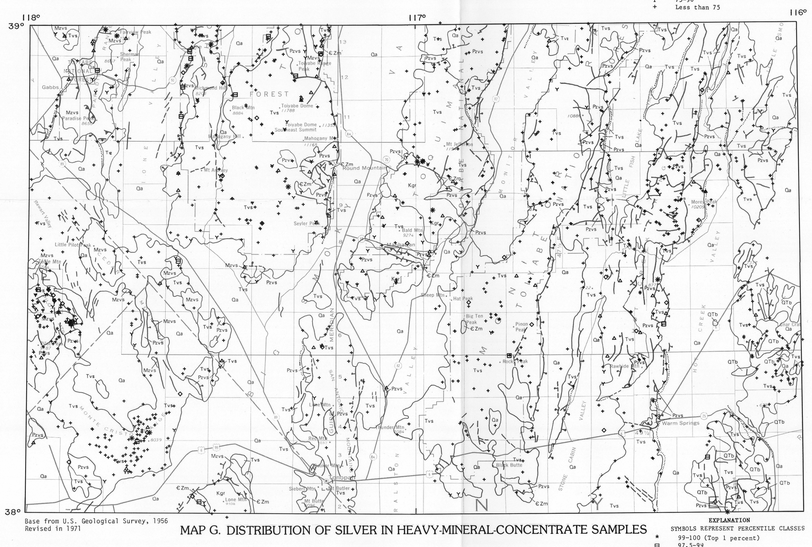
MAP E. DISTRIBUTION OF ARSENIC IN STREAM-SEDIMENT SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



MAP F. DISTRIBUTION OF ANTIMONY IN STREAM-SEDIMENT SAMPLES

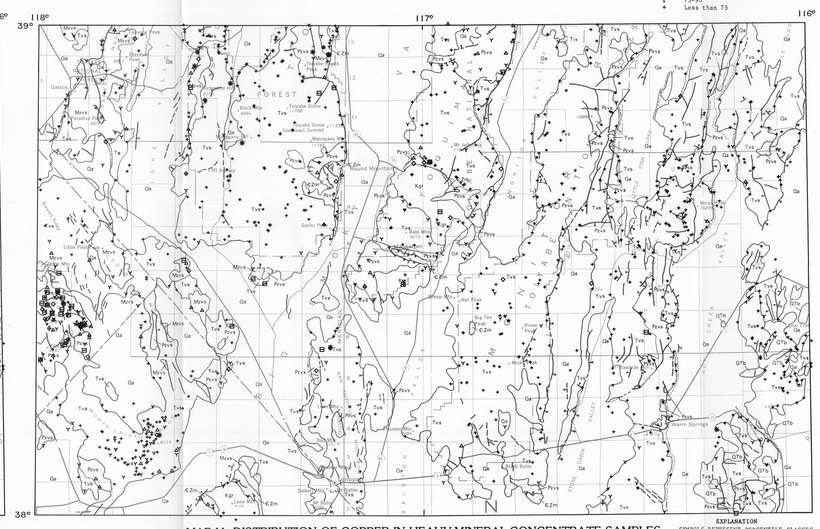
EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



Base from U.S. Geological Survey, 1956
Revised in 1971

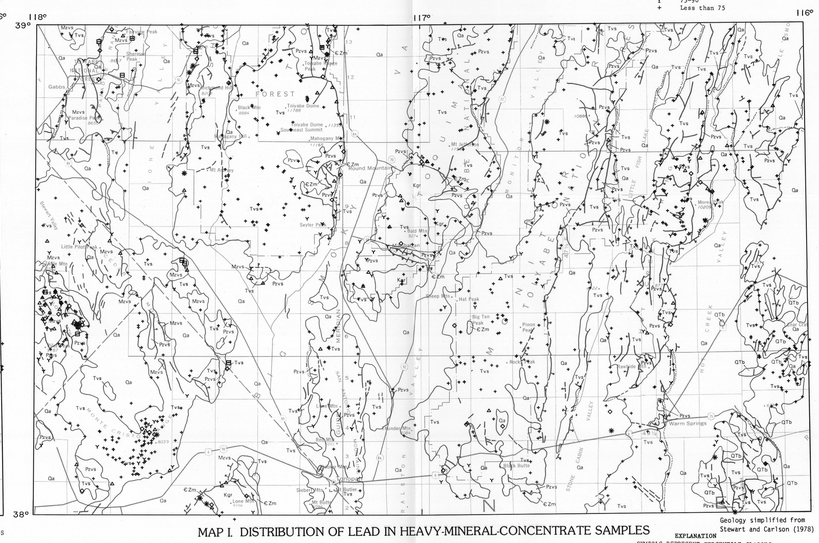
MAP G. DISTRIBUTION OF SILVER IN HEAVY-MINERAL-CONCENTRATE SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



MAP H. DISTRIBUTION OF COPPER IN HEAVY-MINERAL-CONCENTRATE SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75



Geology simplified from
Stewart and Carlson (1978)

MAP I. DISTRIBUTION OF LEAD IN HEAVY-MINERAL-CONCENTRATE SAMPLES

EXPLANATION
SYMBOLS REPRESENT PERCENTILE CLASSES
★ 99-100 (Top 1 percent)
⊟ 97.5-99
◇ 95-97.5
△ 90-95
Y 75-90
+ Less than 75

INTRODUCTION

This report is part of a series of geologic, geochemical, and geophysical maps of the Tonopah 1° x 2° quadrangle, Nevada, prepared during studies of the Area for the Conterminous United States Mineral Assessment Program (CUSMAP). Included here are 21 maps showing the distributions of selected elements or combinations of elements. These regional geochemical maps are based on chemical analyses of the minus-60 mesh (0.25 mm) fraction of stream-sediment samples and the nonmagnetic heavy-mineral concentrate derived from stream sediment. Stream sediments were collected at 1,217 sites. Our geochemical studies of mineralized rock samples provide a framework for evaluating the results from stream sediments.

The Tonopah 1° x 2° quadrangle comprises about 19,100 km^2 (7,450 mi^2) in west-central Nevada (fig. 1). Topography is typical of the Basin and Range province, consisting of angular mountain ranges separated by broad valleys that comprise about half the area. Topographic relief is generally about 1,000 m but in some places is more than 1,500 m. Most of the ranges have well-developed drainages in steep-walled canyons occupied by intermittent streams. The climate is semi-arid to arid. Pinon pine and juniper grow in most places at elevations above 2,100 m, and sagebrush is abundant at lower elevations. Major access is provided by U.S. Routes 6 and 95, and there are numerous county maintained gravel roads and unmaintained jeep trails.

Bedrock geology of the Tonopah quadrangle is a complex mosaic of late Precambrian to Tertiary rocks juxtaposed by numerous thrust and high-angle faults. Useful geologic summaries can be found in reports by Ross (1961), Albers and Stewart (1972), Stewart and Carlson (1978), and Kleinhampl and Ziony (1985). Mineral prospects and mines occur in igneous, metamorphic, and sedimentary rocks of all ages, and mines are particularly abundant in the central and western parts of the quadrangle. The complex geology produces clasts of mixed lithology in alluvium in all drainage basins sampled in this study, and the numerous mines and prospects probably contaminate many drainages.

The geochemical maps in this report are based on analytical results reported by Fairfield and others (1985), Hill and others (1986), and Siems and others (1986). These reports also describe the sample preparation and analytical methods and provide information on the location of the sample sites.

LIST OF UNITS

Qa Alluvial and playa deposits (Quaternary)

QTb Basalt flows (Quaternary and Tertiary)

Tvs Volcanic, intrusive, and sedimentary rocks (Tertiary)

Kgr Granitic intrusive rocks (Cretaceous)

Mzvs Volcanic, intrusive, and sedimentary rocks (Mesozoic)

Pzvs Volcanic and sedimentary rocks (Paleozoic)

€Zm Metasedimentary rocks (Cambrian-Late Proterozoic)

PREPARATION OF SAMPLES

Stream sediments.--The stream-sediment samples were air dried in the laboratory and sieved to minus-60 mesh (0.25 mm) using stainless steel sieves. The minus-60-mesh fraction was selected for this study on the basis of 44 size fraction tests carried out in 1982 which indicated that slightly enhanced geochemical signatures were obtained from this fraction. The minus-60-mesh material was pulverized in a grinder with ceramic plates to attain a minus-100-mesh (0.15-mm) grain size for analysis. Hereafter, the minus-60-mesh fraction of stream-sediment samples is called "stream sediment."

Heavy-mineral concentrates.--The second portion of the sediment was panned to eliminate most clay and rock-forming minerals such as quartz and calcite. Because most of the drainages were dry, the panning was done elsewhere in streams or using large tubs of water. In the laboratory magnetite was removed using a hand magnet, and the heavy minerals were separated using bromoform (specific gravity 2.86). The heavy-mineral fraction was further processed with a magnetic separator. The nonmagnetic fraction was retained for analysis. It was hand ground to less than 149 micrometers. Hereafter, the nonmagnetic heavy-mineral concentrate derived from stream sediment is called "heavy-mineral concentrate."

SAMPLE ANALYSIS

All samples were analyzed for 31 elements using a semiquantitative, six-step direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). All values are reported within a framework of six steps per order of magnitude (0.15, 0.2, 0.3, 0.5, 0.7, and 1.0) and represent approximate geometric midpoints of the concentration ranges. Precision of the method is approximately plus or minus one reporting interval at the 83 percent confidence level and plus or minus two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976).

COLLECTION OF SAMPLES

Stream-sediment samples were collected during the summers of 1982-84. The sample sites were located along first-order (unbranched) or second-order stream drainages generally less than 5 km in length and evident on 1:24,000 scale topographic maps. The sample density was about one site per 10 km^2 of outcrop; the intermontane basin sediments were not sampled. The stream-sediment samples were taken from active alluvium as a composite of several sites across and along the channel within a radius of about 10 m. Because of the numerous mines and prospects in the quadrangle, we attempted to avoid contamination by selecting sites upstream from visible disturbance for mining. Approximately 1 kg of sediment that passed through a 10-mesh (2-mm) stainless steel sieve was collected for the stream-sediment samples, and about 10 kg of the same alluvium was collected for later processing of heavy-mineral concentrate. The sampling was carried out by Suzanne Budge, R.F. Fairfield, Jr., R.H. Hill, J.T. Nash, J.A. Saunders, D.F. Siems, R.E. Tucker, and J.S. Zuker.

DISTRIBUTION OF ELEMENTS IN STREAM SEDIMENTS

Nine maps have been prepared from the stream-sediment data as an aid in describing regional geochemistry and for use in mineral exploration and mineral resource assessment. Six of the maps are for single elements (maps A-F), and three are multi-element maps derived from factor analysis (maps P-R). A brief statistical summary of the data for Ag, As, Cu, Mo, Pb, and Sb is shown in table 1.

Six symbols are used on most of the maps to show the distribution of elements. The six symbols represent classes of concentration, from nonanomalous to highly anomalous. The five classes considered to be anomalous approximate the following percentiles: 99th (top 1 percent, highly anomalous), 99-97.5, 97.5-95, 95-90, and 90-75 (weakly anomalous). Similar classes were obtained by inspection of histograms. Analytical results for Ag, Ba, Cu, Mo, and Pb, determined by six-step semiquantitative spectrography, do not have a continuous distribution, and for these elements classes must be assigned to fit the spectrographic steps. Some of the classes reflect single analytical steps (for example, 70 ppm Cu). In the cases of Ag and Ba, only a few spectrographic steps are represented in the analytical results for these samples, thus only four or five classes are used to represent them

DISTRIBUTION OF ELEMENTS IN CONCENTRATES

Information from heavy-mineral-concentrate samples is presented in nine single-element maps (maps G-O) and three multi-element maps derived from factor analysis (maps S-U). Six classes are used in the plots with the same symbols as used for the stream-sediment maps. Statistical information on Ag, Bi, Cu, Mo, Pb, Sb, Sn, and W, used in making the maps, is summarized in table 2.

Stream-sediment samples were also analyzed using a wet chemical procedure (Vlets, 1978) for the elements As, Bi, Cd, Sb, and Zn, which have high limits of determination when analyzed by emission spectrography. Details of analytical procedures, limits of determination, and analytical results for the stream-sediment and heavy-mineral concentrate samples can be found in reports by Fairfield and others (1985), Hill and others (1986), and by Siems and others (1986).

Mineralogy of some heavy-mineral-concentrate samples was determined using a microscope. For example, we observed that barite ($BaSO_4$) is abundant in concentrate samples containing high amounts of Ba, and cassiterite (SnO_2) is abundant in samples containing high concentrations of Sn. The mineral residence of other elements not established by our studies can be estimated from the results of other more detailed studies of heavy-mineral concentrates (Overstreet and Marsh, 1981). We predict that scheelite is present rather than wolframite, which would be in the unanalyzed magnetic fractions. The combined effects of concentration in streams and by lab methods can produce an enrichment of as much as 10,000-fold relative to primary concentrations of elements in rocks (S.P. Marsh, oral commun., 1984), thus although the analysis of heavy-mineral concentrates enhances some elemental signatures, the analytical values cannot be related back to source rocks in a simple manner.

MULTI-ELEMENT MAPS

Six multi-element maps derived from factor analysis of the stream-sediment and heavy-mineral data sets are shown in maps P-U. These maps portray the distribution of sites of associated elements based on relationships determined by factor analysis (Davis, 1973). In the factor analyses a varimax models were computed with nine factors for the stream-sediment data and seven factors for the heavy-mineral concentrate data. The number of factors was chosen to be large enough to have the factor model explain at least 60 percent, and generally more than 75 percent, of the information on elements of interest. For the factor analysis, the data were converted to logarithmic values and qualified values replaced using a standard scheme in which values of L are given a value one spectrographic step lower than the limit of determination, and values of N are given a value three spectrographic steps lower (for example 10L becomes 3 ppm, and 10N becomes 3 ppm). The factor analysis also computed sample scores that express the composition of individual samples in terms of the factors, a derived variable that can be plotted on maps.

Factor analysis of the stream-sediment data identified several multi-element associations that are plotted on maps P-R. One factor indicates a strong association of Ag and Pb along with weaker associations of Zn, Cu, and Sb. This is an elemental association that we find in mineralized rock samples from several silver districts, most notably Belmont (Nash and others, 1985a). Map P portrays sample scores derived from this factor. Another factor indicates the mutual association of Cu-Ni-Cr-B-Mg, and to a lesser extent Co-Fe-As and Mn. Sample scores derived from this factor are portrayed on map Q. This is a chalcophile suite of elements, but includes the lithophile elements B and Mg, thus we suspect the suite may reflect an alteration assemblage such as chlorite plus pyrite. This suite may be useful in detecting an alteration halo around deposits. A third factor with information on base-forming metals carries most of the information on As and Sb, along with weaker loadings for Cd, Pb, Ni, Cr, and Cu. Map S portrays the distribution of samples with high sample scores for this suite. The mineralogic identity of this suite is not known, but we suggest that it probably is a group of pathfinder elements indicating altered rocks rather than mineralization.

Three multi-element associations of ore metals in heavy-metal concentrates were identified by factor analysis. One factor explains most of the information on the suite W-Bi-Mo-Pb-Cu-Ag. Map T portrays the distribution of samples with high scores for this suite. These elements are characteristic of skarn-type mineralized rocks in several places in the Tonopah quadrangle (Nash and others, 1985c,d). Another factor carries most of the information for Sb and Zn, and to a lesser extent Ag, Pb, and Mo. Sample scores derived from this factor are portrayed on map U. This suite of elements resembles that observed in mineralized rocks from epithermal precious-metal deposits (Nash and others, 1985a). A third factor identifies an association of Ni, Co, Fe, Cu, and to a lesser extent Mo, Pb, and Zn. This chalcophile suite seems to reflect sulfidic alteration, rather than ore minerals, and is perhaps similar to the suite Cu-Ni-Cr-Mg identified in the stream-sediment data. Map O shows the distribution of samples with high scores for this suite.

Although there are uncertainties as to the mineralogic nature of the metal suites identified by factor analysis, we believe the suites are valid and useful because they are similar to suites observed in our geochemical studies of mineralized rocks in the Tonopah quadrangle (Nash and others, 1985a-d). Also, the multi-element maps (maps R-U) are similar to those obtained by superposition of several single-element maps.

DISCUSSION

These 21 geochemical maps are based on more than 2,400 analyses and provide new information on the regional geochemistry of the Tonopah 1° x 2° quadrangle; this information is pertinent to mineral exploration and resource assessment. The geochemical maps, used singly or in combinations, identify most areas of known deposits, prospects, or alteration. There are strong, multi-element indications of most known mineralized areas, and many extensions or new zones are apparent even in these from broadly spaced samples. However, we are aware that the media and methods used, and the low sample density mandated in this regional study, are fallible and could miss significant mineral deposits or alteration. For instance, the Divide and Tonopah Mining districts and the large Hall Mo-Cu deposit are not evident on our maps--chiefly because the drainages in these areas are not well developed and the Hall deposit is west of the main trend of bedrock that guided our sampling in the San Antonio Mountains. Also, a word of caution regarding the heavy-mineral concentrate maps: the nonmagnetic fraction analyzed in this study is optimum for some elements because certain minerals (Ba in barite and Sn in cassiterite) are highly enriched in this fraction, but the mineral separation can cause other elements to be missed if they reside in magnetic minerals (W will be detected if it occurs in scheelite but not if it occurs as wolframite). Finally, there are special problems with sampling gold in the field and in the laboratory because of its density and particulate nature. We suspect that our methods failed to detect gold in many places where it may be present, and the gold detected at 18 localities (Siems and others, 1986) may not be reproducible.

Many types of ore environments are known in the Tonopah quadrangle, and new types may also be present. Two types of ore deposits in the region, tungsten and copper skarns and silver-bearing polymetallic base-metal veins, produce strong and relatively distinct geochemical signatures in rocks and also stand out relatively clearly on these regional maps. Identification of other specific types of ore deposits will be facilitated by the use of these geochemical maps, but other geologic information, especially alteration character and structure, are needed to make the identification specific and reliable.

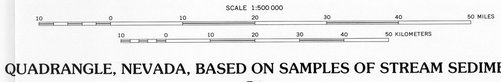


Figure 1.--Map Location

SCALE 1:500 000
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS

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Table 1.--Summary of stream-sediment data for geochemical maps

[Total number of samples = 1,217; n.s., number of samples; (AA), determined by atomic absorption; (S), determined by emission spectrography; Geom. mean, est. all samples, computed from total data set using replaced values for N, L, and G as explained in text.]

	As (AA)	Sb (AA)	Ag (S)	Cu (S)	Mo (S)	Pb (S)
	Statistical Summary					
Valid n.s.	725	516	176	1,136	215	1,237
Minimum ppm	4.0	1.0	0.5	5.0	5.0	10.0
Maximum ppm	800	70	150	150	200	10,000
Geom. mean, ppm	15.2	2.9	1.0	14	8.5	32.5
Qualified: L, n.s.	161	111	50	92	12	1
N, n.s.	331	587	1,009	6	1,006	0
G, n.s.	0	1	0	0	0	0
Geom. mean, est. all samples, ppm	5.6	0.76	0.17	12	1.8	32.4
	Plots					
Class 1 n.s.	804	941	1,038	771	1,002	820
range ppm	0-15	0-2.9	0.5N	5N-15	5.0N	10L-30
Class 2 n.s.	250	172	102	189	121	238
range ppm	15.1-33	3-4.1	0.5L	20	5.0L-5	50
Class 3 n.s.	62	37	--	131	52	79
range ppm	33.1-49	4.2-5.1	--	30	7-10	70
Class 4 n.s.	41	36	41	81	18	47
range ppm	49.1-74	5.2	1.0-1.5	50	15	100
Class 5 n.s.	22	18	20	27	17	20
range ppm	74.1-120	8.1-14	2.0-7.0	70	20	150
Class 6 n.s.	12	13	13	18	7	13
range ppm	120-800	14-70	10-150	100-150	30-200	200-10,000

Table 2. Summary of heavy-mineral concentrate data for geochemical maps

[Total number of samples = 1,181; n.s., number of samples; (AA), determined by atomic absorption; (S), determined by emission spectrography; Geom. mean, est. all samples, computed from total data set using replaced values for N, L, and G as explained in text.]

	Ag (S)	Ba (S)	Bi (S)	Cu (S)	Mo (S)	Pb (S)	Sb (S)	Sn (S)	W (S)
	Statistical Summary								
Valid n.s.	216	825	100	313	131	616	139	198	176
Minimum ppm	1	20	5	10	10	20	200	20	100
Maximum ppm	3,000	15,000G	2,000G	3,000	5,000G	50,000G	15,000	1,500	20,000
Geom. mean ppm	10.1	1,851	159	27.7	41.6	136	625	91	429
L, n.s.	2	3	10	72	5	62	39	12	43
N, n.s.	957	0	1,055	788	1,040	491	997	959	957
G, n.s.	0	346	9	0	1	2	0	3	1
Geom. mean (est. all data ppm)	0.49	3,692	7.1	4.9	3.5	30	69	8.4	39
	Data used in map plots								
Class 1 n.s.	959	658	1,055	866	1,038	920	997	959	957
range ppm	<1	20-3,000	5N	<10	10N	20N-100	200N	20N	100N
Class 2 n.s.	97	--	--	185	39	136	43	104	101
range ppm	1-5	--	--	10-20	10L-10	150-500	200L	20L-50	100L-150
Class 3 n.s.	59	81	64	56	41	66	86	49	66
range ppm	7-10	5,000	5L-120	30-50	15-20	700-1,500	200-500	70-150	200-500
Class 4 n.s.	30	26	26	28	32	36	28	39	31
range ppm	15-30	7,000	150-500	70	30-100 5,000	2,000-	700-2,000	200-500 1,500	700-
Class 5 n.s.	17	62	19	32	18	11	17	14	18
range ppm	50-150 15,000	10,000-	700-1,500	100-150	150-500 10,000	7,000- 5,000	3,000-	700 5,000	2,000-
Class 6 n.s.	13	346	15	14	13	12	10	12	10
range ppm	200-3,000	>15,000 2,000G	2,000-	200-3,000 5,000G	700- 15,000G	15,000- 10,000G	7,000- 5,000	1,000- 20,000G	7,000-

REGIONAL GEOCHEMICAL MAPS OF THE TONOPAH 1° X 2° QUADRANGLE, NEVADA, BASED ON SAMPLES OF STREAM SEDIMENT AND NONMAGNETIC HEAVY-MINERAL CONCENTRATE

By
J. T. Nash and D. F. Siems

1988

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